

“Introduction to Antennas” – an antenna training DVD

Alan Nott BEE, CEng, MIEE

Antuition Enterprises, 4 Kipling Street, Moonee Ponds, Victoria, Australia, 3039

Abstract.

Understanding antenna characteristics and how they are effected by their surroundings is essential to obtaining the best performance from communications assets. Communications personnel responsible for the choice, configuration and orientation of antennas, and/or frequency management, rely on this knowledge for daily performance of their duties. The HMAS Cerberus Radio Frequency Management Course regularly delivers such training to a wide range of students, both from Australasia and South East Asia. Students have diverse academic backgrounds and experience, and may not have English as a first language. Because of this, teaching of underlying concepts needs to be addressed with a minimum of detailed mathematics. A comprehensive range of image-based training material developed privately by the author has been captured on a DVD entitled “Introduction to Antennas”. This paper discusses the DVD and some of the material.

Background.

For over a decade, the author has been a guest presenter at a range of conferences and courses in Australia, in particular the HMAS Cerberus Radio Frequency Management (RFM) Course. The RFM course, unique in the Southern Hemisphere, provides training for Australian and New Zealand Defence Communications personnel, as well as corresponding personnel from South East Asia. The transient nature of tactical communications implies a need to “get it right first time”, and this is promoted by a thorough conceptual understanding of the issues involved - an antenna intuition. Because RFM students have a wide range of academic backgrounds, and many do not having English as a first language, material needs to be presented so that it can be easily understood and remembered by students at all levels. Explanation of electromagnetic concepts using images rather than detailed mathematics is key to the success of this work. The images are the product of fifteen year’s involvement with electromagnetic visualisation. They include still images and animations of data from NEC and basic mathematics, as well as “artist’s impressions”, and cover electromagnetics, electromagnetic interactions, propagation, and performance of antennas in the real world.

Since 1990, the author has been developing NEC graphical interfaces. Initially, AutoCAD was customised to provide both a powerful 3D model creation environment, and display of 3D radiation patterns and near field contours [1]. Acquisition of 3D Studio (DOS) added “realistic” 3D rendered images of radiation patterns as animations, or suites of still images for use in antenna training aids [2]. With the need to run up to 30000 NEC models in a single batch, NEC was modified to read command line arguments for input, output and Sommerfeld file names. Input and batch file creation as well as post-processing was handled by purpose-written applications. Data compression techniques were developed to provide efficient storage and retrieval of radiation pattern data [3]. This allowed interactive display of radiation patterns as traditional graphs, and together with a modest ionospheric model, as skywave footprints. Reference [4] gives more detail of this work. In 2002, Defence’s Navy Video Unit (NVU) were tasked by the RFM course to prepare a series of DVDs containing this course material. The first DVD “Introduction to Antennas” has been completed.

Preparation of DVD material

The 82-page DVD script evolved from several of the author’s scripts for various courses and presentations. Because of its DOS origins, all image material had to be reworked for the higher resolution DVD format using the Windows version of 3D Studio – 3DMAX. Creation of the animations in the DOS environment made extensive use of an embedded language to provide software generation of keys to manipulate scene entities, often up to several thousand per animation frame. This capability was not available in 3DMAX, and while the DOS animation files could be imported, some of the more extensively used animation keys either were not transferred or were modified. As a consequence, a significant amount of manual rework was required in 3DMAX – a time-consuming and error-prone process.

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More than 150 animation files and 7000 still images were created for the DVD. Still images were mainly used to create animated colour maps, such as HF footprints, the images being created by a purpose-written application. This application read compressed antenna pattern data from NEC, performed ionospheric ray-tracing, plotted the resultant area coverage to the screen pixel by pixel and saved the resulting image as a bitmap (.BMP). The process was automatically repeated across the range of parameters of interest (eg frequency), and the resulting images were batch converted to TARGA format for insertion into the DVD creation process.

The evolution of the script, rework of animation files, creation of still images and development of a number of new processes took some eighteen months to complete. This required the creation of some 80 Gbyte of images and other data in over 12000 files. Of these, 6 Gbyte were passed to NVU for DVD processing. Management of this amount of data raised some interesting configuration management problems, and considerable effort was spent developing methods to track hierarchy and versions of the files involved for each animation, and its progress/status. The 500-mile geographical separation between the author and NVU also contributed to the configuration management issue.

DVD coverage

The material on the DVD has been specifically developed to provide a significant understanding of complex electromagnetic phenomena, antenna interactions and performance, without resorting to complex mathematics. While the 88-minute DVD can be viewed in a single session, it is preferable for the student to navigate through manageable sections at his own pace.

Chapters 1 to 7 cover the generation of electromagnetic fields, electromagnetic radiation from a dipole antenna, near and far fields, antenna equivalent electric circuits, coupling, resonance, reflection, absorption, scattering and refraction. These lead the student from the simple concepts of charge movement (currents) and electromagnetic wave generation, to an understanding of electromagnetic interactions with materials and objects.

Chapters 8 and 9 (propagation, refraction from the ionosphere) build on material in earlier chapters to gain an understanding of propagation and signal paths.

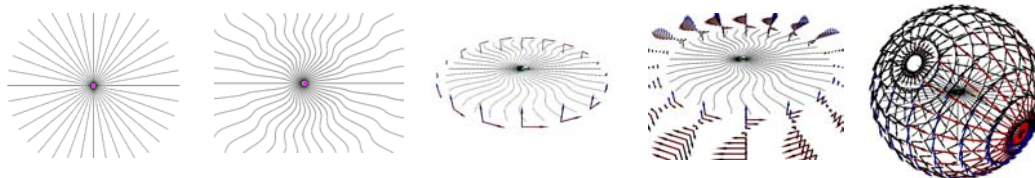
Chapter 10 introduces the concept of radiation patterns, both in two and three-dimensional representations.

Chapter 11, which comprises almost half the DVD, takes the knowledge from previous chapters and looks at the interactions between antennas, their platforms and the environment. There is a conscious bias towards the HF band, as communications at these frequencies are generally poorly understood. However, most concepts presented are readily extrapolated to other frequency ranges.

The DVD has application to anyone who is seeking to gain an understanding of the complexities of electromagnetic radiation and antenna performance, but at this stage, does not wish to become embroiled in the mathematics.

Examples

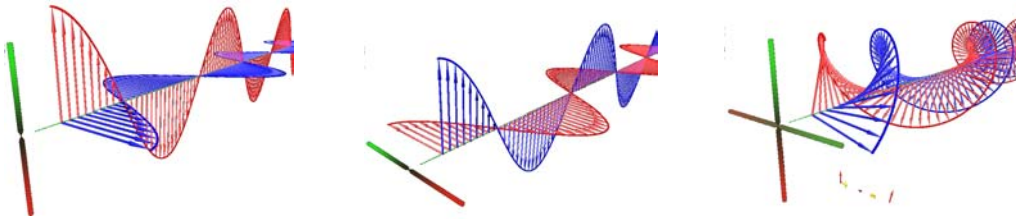
The following examples are derived from single frames from a small fraction of the 200 or so animations that have been adapted for the DVD. Translation from animations to still images together with low-resolution non-colour printing limits the visual impact. The full-screen, full-colour animated versions are considerably more enlightening.



Figures 1 to 5: Evolution of electromagnetic waves from cyclic charge movement.

Faraday's 'lines of force' are introduced in two dimensions (Figure 1). This is expanded to illustrate the effect of cyclic charge movement on the lines of force, the creation of a transverse

component of electric field, and a travelling electromagnetic wave (Figure 2). An analogy is made with a rope being wiggled, introducing to the student the concepts of retardation due to finite propagation speed along the rope, wavelength, and the relationship between wavelength, frequency and propagation speed. A single row of E and H vectors is added (Figure 3), and extended (figure 4) to show the wave propagating outwards. Finally a single layer of animated E and H vectors are plotted on an enclosing sphere (Figure 5). Figures 3 to 5 illustrate maximum radiation broadside to the charge movement, and no radiation end-on (ie a dipole pattern). The concept of polarisation is introduced, and can be seen from the relation between vector directions and charge movement (ie current in a radiator). Figures 1 to 5 were prompted by Dr. E.K. Miller's discussions on the 'Kink' model of an electron [5].



Figures 6 to 8: E and H wave polarisations from vertical, horizontal and crossed dipoles.

The crossed dipoles are included to illustrate the more complex polarisations that arise from multiple radiating sources, and with currents having different directions and phases. A further series introduces the concept of coupling into nearby structures and the need to consider the whole platform as the radiator, and not just the antenna per se. This concept is taken further in the "real world" section, both in relation to antenna arrays and antennas mounted on specific platforms.

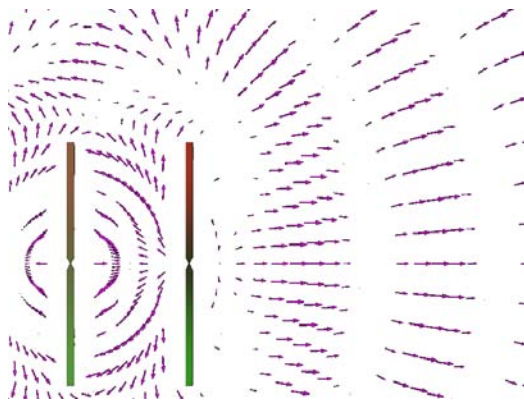
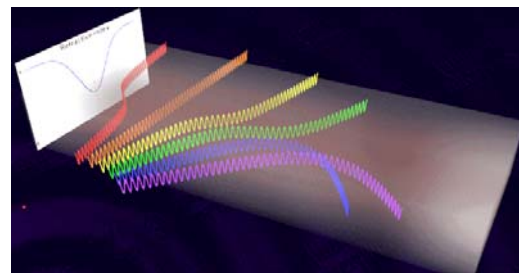
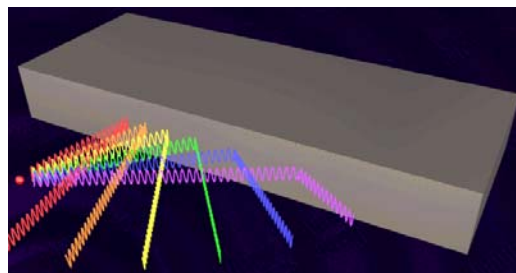


Figure 9: Vector plots of near fields around a driven dipole near a passive dipole.

NEC Near-field output data was used to create animations of electric, magnetic and Poynting vectors around a dipole. These show the complex field structure close to the radiator— a subject not well covered in texts. Close to the dipole the electric field and Poynting vectors rotate, indicating the presence of both radiating and the quadrature non-radiating fields. Rotation falls off with distance because of the greater falloff of the non-radiating field.

Figure 9 shows the effects of reradiation from a passive dipole.



Figures 10 and 11: Reflection from a plane surface, and refraction in a graded medium.

These images are from a series of animations on electromagnetic interactions that cover reflection, absorption, scattering and refraction. A variation of the image of Figure 10 has a translucent reflecting material, allowing the image of the source and its rays to be seen. In Figure 11, the curved paths lead to initial discussions on ionospheric refraction.

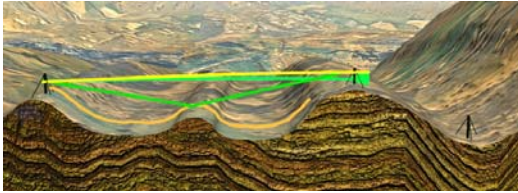


Figure 12: LOS paths

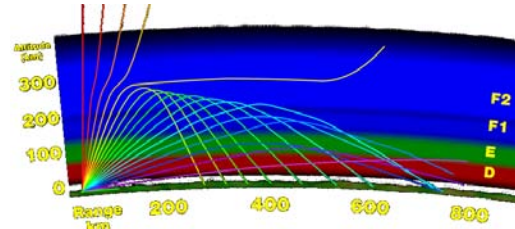


Figure 13: Ionospheric paths

Figures 12 and 13 are from the propagation sections that cover aspects of LOS, and skywave. Animations show the variety of paths between two points, and the delays for different paths are easily seen. Fresnel zones, skip zones, multipath and ionospheric effects are also covered. A related section discusses ionospheric sounding.

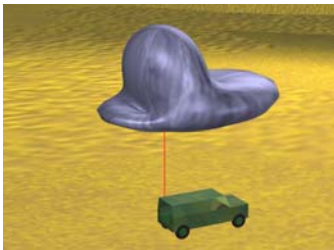


Figure 14: 3D Radiation pattern from vehicle whip

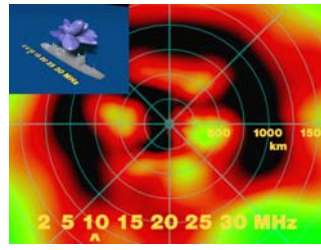


Figure 15: FFG radiation pattern and footprint –Whips up

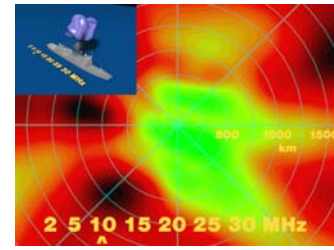


Figure 16: FFG radiation pattern and footprint – Whips down

Figures 14 to 16 are from the “Antennas in the Real World” section, and show the effect of the platform on the radiation pattern of whip antennas. Figure 14 shows the effect on the whip pattern of a resonance in the canopy bow around 22 MHz. The footprints in Figures 15 and 16 show the advantage of having the whips lowered for short-range (NVIS) coverage.

Conclusions

The images presented are a small sample of those that have been developed. Comments received on the “Introduction to Antennas” videos, as well as the author’s experience during live presentations of this material confirm that the subject matter is being presented in an easily understood way. Translation to an interactive DVD format will allow the user to proceed at his own pace, revisiting sections as necessary. Indications are that this DVD, together with others planned to cover related subjects, will provide an excellent learning environment.

The DVD has also been recognised by the animation industry, winning the Education and Training category of the 2004 Australian Effects and Animation Festival.

References

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- [5] E.K. Miller and G.J. Burke, "A multi-perspective examination of the physics of electromagnetic radiation", *ACES Journal* Volume 16, No. 3, 190 - 201, November 2001.